

HIGH PRESSURE SENSOR WITH KNURL PRESS-FIT ASSEMBLY

FIELD OF THE INVENTION

This invention in general relates to high pressure sensors and, more
5 particularly, to a high pressure sensor assembly.

BACKGROUND OF THE INVENTION

High pressure sensors are used in a variety of applications. Such applications
can include hydraulic systems in machinery or automotive fuel injection systems. In
10 particular, high pressure sensors can be used in automotive applications such as
transmission fluid pressure sensing, oil pressure sensing, fuel injection pressure
sensing and brake fluid pressure sensing. Typically, such applications subject the
sensor to an adverse environment requiring precision assembly using durable
materials. In addition, pressure sensors in automotive applications are subject to
15 stresses other than the fluid pressure. For example, installation and assembly of the
sensor along with temperature changes during use submit the sensor to external forces
that the sensor must be capable of withstanding. These requirements have resulted in
pressure sensors with complex, multi-part assemblies that incur a high cost.

One prior art sensor provides a three-piece stainless steel pressure sensor,
20 which requires two pieces to be welded together and then crimped into a metal
housing with an o-ring seal. However, the welding and crimping process add cost,
and the o-ring seal cannot seal high pressures. The fluid is in contact with the weld
which may present corrosion issues. Also, the o-ring limits the amount of pressure
that can be applied

25 Another prior art pressure sensor assembly has a sensor header which is laser
welded to a metal housing. However, the laser welding is a process requiring

expensive equipment and good accuracy, which adds cost. In addition, the laser welded material must be compatible with, and able to withstand, the fluid media exposure. Further, this assembly provides a very rigid form of attachment which may transmit too much mounting stress resulting in errors in the pressure signal.

5 Another prior art pressure sensor includes a separate pressure port which is held in a metal housing with the use of a spring clip. It is also locked in place with an epoxy material. This process requires an extra part and an adhesive material that must undergo some cure process.

10 Another prior art pressure sensor provides a simple sensor design that is glued into a metal baseplate housing. Unfortunately, this type of assembly is not a strong method of retention, especially in tension. Also, this assembly requires a cure of the materials.

15 Therefore, a need exists for a low cost, high pressure assembly that is able to withstand the internal and external stresses in an automotive environment. It would also be desirable to provide such improvement in a simple, one-piece assembly that limits the potential for lateral movement damage.

BRIEF DESCRIPTION OF THE DRAWINGS

20 The features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood by making reference to the following description, taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify identical elements, and wherein:

FIG. 1 is an exploded and cutaway view of a pressure port and housing in accordance with the present invention;

FIG. 2 is a cross-sectional view of the assembly of the pressure port and housing of FIG. 1; and

5 FIG. 3 is a flow chart of a method, in accordance with the present invention.

While the invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the
10 invention is to cover all modifications, equivalents and alternatives falling within the broad scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 The present invention provides a low cost, high pressure assembly that is able to withstand the internal and external stresses in an automotive environment. The sensor assembly is a simple, one-piece assembly that is semi-rigid, which allows some lateral movement to prevent mounting stress sensor error.

Referring to FIGs. 1 and 2, the present invention provides a high pressure
20 sensor assembly using a knurled, one-piece pressure port 10 to be press fit into a metal baseplate housing 12. Preferably, the knurl is a straight-knurl. However, a diamond, or other pattern, knurl can also be used. The pressure port 10 is roughly cylindrical and has a mounting boss 14 with knurls 16 formed around a diameter thereof. Preferably, the knurls are straight knurls oriented parallel to an axis of the
25 pressure port. The straight knurled pattern is easy to produce on the pressure port

using known rolling or cutting techniques and adds little cost to the part. Due to the nature of the interference between the two pieces, tight tolerances, which are common for press fit designs, are not required. The mating hole or receptacle 18 is simply drilled into the mating housing 12 using a standard drill size with standard tolerances.

- 5 The tolerances required on the knurls 16 and the receptacle 18 are larger than standard press fit tolerances therefore do not add significant costs.

The hardness of the metal components is critical to the operation of the press fit. The knurled portion is much harder than the housing, thus allowing the housing material to deform away from the peaks of the knurls and flow into the open spaces of the valleys of the knurl. Specifically, the pressure port is made of hardened stainless steel and the housing is made of aluminum. Therefore, during assembly the peaks of the knurls press into the softer housing receptacle deforming material around the knurl teeth resulting in a tight fit around the pressure port. The valleys of the knurls allow for some extra space for the deformed material to press into.

- 15 In addition it is very simple to assemble the components together. It can be done manually or with automated equipment to achieve good reproducibility. The attachment process is extremely simple and does not require any expensive equipment. In addition, no extra fasteners are required for the assembly. The parts are essentially held so they are on the same axis and pushed together. As the port reaches its final position a flat shoulder 20 abuts the surface of the housing 12 thus resulting in an exponential increase in force per unit displacement, indicating that the pressure port is fully seated. The receptacle 18 of the housing 12 conforms about the knurls 16 of the mounting boss 14 and forms a semi-rigid mount.

- 25 The attachment is semi-rigid, meaning that it is rigid against push-out and torque-out forces but does not totally constrain the port allowing some lateral

movement 22 if needed. Therefore, the present invention has better stress isolation of the pressure port to external stresses which results in better accuracy in the pressure measurement. In application, the pressure port has the potential to have a lateral (i.e. side loading) force applied to the port at some distance below the knurl. This is because the pressure port is pressed in and can resist lateral forces to some degree depending on a number of factors including: the interference amount, the distance at which the force is applied relative to the press fit area (i.e. moment arm), the softness of the material pressed into, and the magnitude of the force applied.

In a preferred embodiment, to provide a leak tight junction, a seal 28 is provided between the port and the housing. The seal can be made using a dispensed seal material, an axial o-ring or gasket seal on the shoulder, or a radial seal above the knurled diameter. Preferably, a silicone glue is dispensed around the top of the knurled portion between the port 10 and the housing 12. This seal also allows lateral movement of the port while preventing leaks.

In practice, the present invention uses a 30 tooth-per-inch straight knurl pattern. The knurl outer diameter ranges from 8.94 to 8.81mm and the peak to valley distance or tooth depth is approx. 0.6096mm (using a standard knurl tolerance). The receptacle of the housing is 8.5mm +/-0.05mm which is a standard drilled hole tolerance. The dimensions were chosen, because they are easy to maintain without any special attention, which results in no additional costs.

Also important are the length of the knurl and the depth of the receptacle. In some materials that are brittle or have a high modulus of elasticity, the knurl actually cuts the material away to some degree as well as local deformation on the peaks of the knurls. Therefore, there is the concern of metal chips being created inside the pressure sensor module which could disperse and cause electrical problems. To

resolve this issue, the length of the knurl was made less than the depth of the receptacle such that the knurl pattern did not go through the entire depth of the receptacle during assembly. This leaves an undeformed portion in the receptacle that actually traps any chips in place. Specifically, the straight knurl length is three
5 millimeters and the depth of the receptacle is four millimeters, leaving one millimeter of undeformed space to trap the debris formed. Note that this chip debris phenomena does not occur in materials with higher ductility as the material would just deform and not create any metal chips. In addition a bevel is provided on the leading edge of the teeth of the straight knurls to assist in alignment during the press fit and to ease
10 assembly by providing gradual deformation with less potential for chips. Preferably, the bevel is at 60°.

The length of the knurl, especially in materials that work harden, such as plain steel, is an important factor as to the ease of the press fit assembly process. As material is deformed, the deformation makes the material harder and increases its
15 strength. Therefore as the material moves when the knurl presses into it, it will locally increase in strength and the more it presses thru, the more material gets deformed in front of it making it harder and harder to press as it goes in. Some materials will react differently, based on their material properties and therefore, they may not be optimal for press fits greater than a certain length. The present invention
20 uses hardened stainless steel for the port and aluminum for the housing, which readily deforms.

In operation, the top side of the pressure port 10 contains an integral diaphragm 24 that is exposed to the ambient pressure inside the pressure sensor module. A piezo-resistive transducer deposited in silicon is bonded to the diaphragm
25 24, to measuring pressure relative to the atmospheric pressure surrounding it. The

bottom of the port 26 is coupled to the fluid to be measured. In a transmission fluid application, the pressure range that the bottom of the part is exposed to is a standard pressure that is used in transmission ducting, and can vary from 0 to 70 Bar gauge pressure. However, it should be recognized that the pressure sensor assembly of the present invention can be used in various pressure applications including engine oil pressure, braking systems, fuel injection systems, and the like.

Referring to FIG. 3, the present invention also provides a method of assembling a high pressure sensor with knurl press-fit. The method includes a first step 30 of providing a pressure port having a material with a first hardness and a housing having a material with a second hardness less than the first hardness. Specifically, a hardened stainless steel pressure port and an aluminum housing are provided. The pressure port has a mounting boss and the housing has a receptacle for receiving the mounting boss, wherein a length of the knurls that is less than a depth of the receptacle.

A next step 32 includes configuring the mounting boss of the pressure port with knurls thereon. Preferably, the knurls are straight knurls oriented parallel to an axis of the pressure port. The knurls of the mounting boss and the receptacle are configured to have an interference fit. Preferably, this step also includes configuring a shoulder on the mounting boss. The straight knurls are formed having a peak-to-valley distance of less than one millimeter, and preferably 0.6 millimeter. An outer diameter of the straight knurls of the mounting boss is less than 0.5 millimeter larger than a diameter of the receptacle, and preferably 0.4 millimeter larger than a diameter of the receptacle.

A next step 34 includes pressing the mounting boss of the pressure port into the receptacle of the housing along a direction of the axis such that the knurls deform

the receptacle of the housing to conform about the knurls to define a semi-rigid mount. With a shoulder on the pressure port, the pressure port is pressed into the receptacle of the housing up to the shoulder.

5 A next step 36 includes applying a seal to the press fit area to seal the pressure port. Preferably, this seal is a silicone glue disposed in a radial seal on top of the knurls between the pressure port and the housing.

The present invention provides a semi-permanent technique for attachment that provides a semi-rigid mount and still provides isolation from mounting stresses. The assembly process is very simple and does not require any expensive
10 manufacturing equipment.

The above description of the present invention is intended to be exemplary only and is not intended to limit the scope of any patent issuing from this application. The present invention is intended to be limited only by the broad scope of the following claims.

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